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ABSTRACT

The one model of science instruction that works for all students has not yet been discovered, and such a perfect approach may not exist. Of the existing models and the best practices that are coupled with those models, no approach can meet the needs of all learning disabled students. Science educators must work with special education specialists to determine the best practices for particular students. This paper provides a synthesis of empirically supported best practices for teaching science to students with learning disabilities. (Contains 45 references.) (CCM)

A SYNTHESIS OF EMPIRICALLY SUPPORTED BEST PRACTICES FOR SCIENCE STUDENTS WITH LEARNING DISABILITIES

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Best Practices for Science Education

National Standards Documents

Science literacy for all Americans! This noble sentiment echoes in the documents which form the philosophical and practical foundation for science education reform in the United States: *Science for All Americans (SAA)* (American Association for the Advancement of Science, 1990), *Benchmarks for Science Literacy (BSL)* (American Association for the Advancement of Science, 1993) , and the *National Science Education Standards (NSES)* (National Research Council, 1996). These documents synthesized current ideas among scientists and science educators about the best practices for developing a population that will become scientifically literate adults. *SAA* emphasized "teaching for understanding", and described several aspects for doing that in science education. The *BSL* recommended a foundation of content knowledge, and a coherent sequence of topics and concepts shaping science instruction so the knowledge and skills gained would last through adulthood. The *NSES* emphasized an inquiry-based approach and prescribed that approach as the most desirable for teaching science. The *NSES* also recommended a "less is more" approach to curricular choices. These three documents

emphasized inclusion of science for all populations in K-12 schools in the United States as a foundation for meeting the goals set in the documents.

Science Education Research

There are other factors which influence decisions about the best ways to structure K-12 science instruction. Driver's (1982) research into the characteristics of young learners led to a revised Piagetian approach to science instruction, constructivism. Subsequently, the study that led to the video "A Private Universe" (Schneps, 1989) brought into sharp focus the fallacy of assuming that traditional instruction led to a common core of learning and understanding, and reinforced the beliefs of many in constructivism.

International Science Tests

The results of the Third International Mathematics and Science Study (TIMSS) (Harmon et al., 1997) have provided a sobering reminder that students in middle and high schools in the United States are performing poorly in science compared to students in many other countries. The TIMSS data show that middle and high school teaching in the United States differs from higher scoring countries in the time spent on fundamental concepts. This echoes and supports the NSES recommendation of the need for a "less is more" approach.

State Science Standards

State science standards are another factor in choices for science instruction. Most states have in place a set of science standards which stipulate what is to be taught, and, in many cases, how

things are to be taught. Indiana (Indiana Department of Education, 1997), a state which earned a grade of "A" for its science standards (Lerner, 1998) incorporated "Action shots" -- sample science lessons -- into their standards document. Virginia's "D" science standards emphasized a grade by grade list of science content which a student should "know and understand", yet Virginia's standards (Virginia Board of Education, 1995) provided no recommendations on how to teach to these standards. Both these states and many other states are developing student tests to assess the meeting of their standards, and schools, teachers, and students are being held accountable for student achievement on the tests. National tests for science achievement loom in our future as the pressure to improve education increases.

Classroom Practices

What is a teacher to do, to meet the challenge of the science reform documents and enable all their students to be science literate? What are the recommended classroom best practices for meeting these goals? What practices have teachers used in the recent past to teach science?

Reform and Best Practices

Words and phrases found in the national science reform documents and recent research in science teaching (i.e., American Association for the Advancement of Science, 1990; American Association for the Advancement of Science, 1993; Lawson, Abraham & Renner, 1989; Tobin, Tippins & Gallard, 1994) on best practices in K-12 science education include the following: Inquiry, constructivism, learning cycle, hands-on (also hands-on/minds-on), process-based,

laboratory, and Socratic method. In their study of the curriculum projects of the 60s, Shymansky, Kyle and Alport (1983) found that inquiry-based approaches to science instruction had a positive effect on student achievement. The curricula studied by Shymansky, et al., incorporated aspects of the learning cycle, which became a model for structuring science instruction.

Inquiry

The word "inquiry" is often used synonymously with constructivism, the learning cycle, hands-on, process-based, and problem-based instruction. "Inquiry" generally refers to question-generated instruction. In some inquiry settings, questions are asked by students. In others, teachers ask guiding questions or manipulate student responses until the desired questions are raised by the students.

The Learning Cycle

The learning cycle has been defined as a method of instruction characterized by the use of an investigation prior to formal introduction of a science concept (Tobin et al., 1994). There were three stages to the original learning cycle of the SCIS program: exploration, concept development, and concept application. Though the stages have been revised through the succeeding years (Bybee et al., 1989), the essential structure continues to be (a) an exploration activity occurs early in the instruction, (b) teacher direction is emphasized after the exploration, and (c) a concluding activity may or may not be followed by assessment.

Recent research on the learning cycle instructional approach indicated student achievement and attitudinal benefits (Abraham, 1989; Glasson & Lalik, 1990; Lavoie, 1992; Scharmann, 1992), yet cautioned that the role of peer and teacher interaction in such instruction has yet to be fully investigated. Nonetheless, the learning cycle appears to fit into the category of "best practice" for science instruction.

Laboratories

The use of laboratories in science teaching and learning seems to fit into both inquiry-based and traditional instruction, though laboratories developed with an inquiry approach should differ in process and outcomes from laboratories developed with a traditional approach. Inquiry-based laboratories can be student-generated, and involve outcomes which are often unknown by the students until the lab is completed. Traditional laboratory instruction involves confirmation-type labs, which reproduce experiments and have a finite set of correct answers.

Traditional Approaches

Traditional approaches to science instruction such as direct instruction have not received as much attention in the science reform documents as have inquiry-based approaches. Nonetheless, K-12 teachers have not abandoned such traditional practices in their classrooms. Thus it is appropriate that science education researchers continue to factor these ideas into their projects. Traditional instruction is characterized by descriptors such as: Textbook-based, content-based, and laboratory.

Textbook and Content-based Instruction

Textbook-based and content-based instruction are similar, in that both usually rely upon written information for the conveyance of knowledge. Coverage of the content was a motivation for dependence upon the textbook for information, and teachers partitioned their class time according to the goal of coverage, with little consideration for student understanding (Abraham, 1989).

Laboratories

Science laboratory activities in traditional classrooms tended to be "cookbook" - emphasizing following the directions of the laboratory packet and performing the activities accurately and skillfully. There was little opportunity for student planning or interpreting of results (Tobin, 1990).

Use of Traditional Instructional Approaches

Tobin and Gallagher (1987) and Tobin (1990) found that teachers continued to employ instructional strategies which emphasized the traditional laboratory approach and textbook/content emphasis despite the lack of consistency with the best practices delineated by the science education research community and the reformers. The influence of tradition and the pressures of the culture to cover the content and teach so students will be successful on tests may explain this phenomena. It is also possible that traditional approaches do benefit students in some ways not examined sufficiently or not understood within the popular culture of science

education. Calls for reform in science education consistently support higher achievement for all Americans in science. Many classroom teachers responded to calls for increased achievement by increasing the amount of content covered in textbooks and lectures. However, evidence regarding outcome measures tended to support less use of textbook and lecture approaches and greater reliance on activities-based approaches.

Students with Learning Disabilities

At the time the reform initiatives were developed, dramatic changes in service delivery options were being called for on behalf of students with disabilities. Science education is one area that is consistently considered to be an appropriate area for inclusion of students with disabilities (Cawley, 1994; Patton, 1995). Most of the initiatives in science education, although supportive of the concept of science for all Americans, have been developed primarily with typical students in mind. Also, many practicing science teachers have little training or experience in identifying and meeting the needs of students with disabilities (Norman, Caseau & Stefanich, 1998). Because students with learning disabilities (LD) comprise the largest category of students in special education, science educators are very likely to work with students who have LD in their classrooms. In the next section, we provide a brief overview of the major characteristics exhibited by students with LD. We also discuss factors which may add to the variability of individual students within the category of

The Rate of Occurrence of Learning Disabilities

Although the term learning disabilities is a relative newcomer in the field of human services, its roots can be traced back to medical practitioners before the turn of the century. Reports as early as the 1890s described children who although typical in almost every other area of development were unable to acquire the skill of reading (Hallahan, et al. 1996). In the early twentieth century estimates of this condition's prevalence were thought to be, at most, one in 1,000 (Hinshelwood, 1917; Thomas, 1908). At the close of the twentieth century, prevalence rates for the condition of learning disability range approximately from five to ten percent of the U.S. population of school-aged children (Kavale & Forness, 1995).

Variability within the Population of Students with LD

The rise in prevalence rates suggests that students identified with this problem may be very different than those identified in the past. Probably, this reflects a broadening of the definition of LD so that the variety of students represented by this terms is wider than ever before. The variation in prevalence currently existing in American schools also suggests that many factors besides individual student characteristics affect the identification process. Therefore, students with LD may not only be quite different from each other within school districts or buildings and but between districts as well. That is, extra-student factors may lead a student with learning or behavior problems to be identified as having a disability in one district but not considered to have a disability in another district. All of this is to point out the difficulty in prescribing treatments from students with LD. Because of the difficulty in describing students with LD, it is

a very daunting task to prescribe treatments which can work across a large number of students with LD. Nevertheless, several important characteristics common to most students with LD can be identified in the special education and psychology literature.

Characteristics of Students with LD

General characteristics of population

Kavale and Nye (1985-1986) examined the variables for which the performance of students with and without LD has been shown to be different. In all, 38 variables were grouped together into four categories or Domains: linguistic, achievement, neuropsychological, and social/behavior. Kavale and Nye then applied meta-analytic techniques to calculate effect size statistics for the variables. Effect size statistics express the magnitude and direction of difference between groups on a given variable on a z score scale. An effect size of zero would indicate no difference between the groups at all. An effect size of ± 1.00 indicates a very large difference between the groups. Generally, effect sizes beyond the -0.25 to $+0.25$ range are considered notable and beyond chance variation. Effect sizes are also given signs to denote which group demonstrates the superior performance. In the case of the Kavale and Nye meta-analysis, a positive effect size favors the group of students without LD and a negative effect size favored the group of students with LD.

The overall mean effect size for LD and non-LD group differences in the Kavale and Nye study was +0.660 (SD = .585). According to this effect size, approximately 75% of the students

with LD could be clearly differentiated from students without LD across all four domains (Kavale & Forness, 1995). When the four domains were examined within the groups of students with LD, the greatest differences were found in the language domain, followed by achievement, neuropsychological measures, and social/behavioral indices respectively. Although these differences could be ranked in the preceding order, no statistically significant difference was found among the domains. Thus, this study and analyses of other characteristics research (e.g., Kavale, Fuchs & Scruggs, 1994) found that students with LD were clearly distinguishable from their peers without disabilities but no single domain emerged as the hallmark of the condition. Practitioners developing interventions for students with LD must therefore, remain sensitive to variability within the group. An intervention that is helpful to one student may be irrelevant to another student.

Sources of individual variation within the population

The complexity of intervention with students who have LD is further complicated by the interaction of individual strengths and weaknesses and the specific task demands faced by the student. Levine, et. al, (1993) described the ability of an individual to use a specific strength to compensate for a limitation as functional overriding. "An example of such functional overriding is seen when a student with excellent language skills and deficient nonverbal reasoning conceptualizes conventionally nonverbal mathematics tactics through a linguistic route. Such alternative or unorthodox may or may not engender success" (Levine et al., 1993, p. 237).

Conversely, functional undermining occurs when a "...function is so inadequately developed or insufficiently automatized that it drains excessive mental effort (i.e., cognitive/mnemonic/attentional resources from one or more other (ordinarily intact) elemental functions needed to generate a production component. For example, a child with a motor dyspraxia may have to exert so much effort to form letters that little if any resource remains for adequate spelling" (Levine et al., 1993, p. 237). Further, the effects of functional overriding and functional undermining may be content specific such that a student with a strong interest or affinity for animals may perform noticeably better in a biology course than she might in a physics course. Therefore, the effects of learning disabilities may appear to come and go depending on the draw of competing mental processes and the course material itself. This phenomenon is often mistaken for a motivational or self-discipline problem and in some students (even students with LD) it is. However, in other cases, the implication of this theory is that interventions and accommodations necessary for a given student in one class or task may not be helpful or could possibly interfere with learning in another class or task given the interaction of the individual's specific characteristics, the class, task, and the constellation of other cognitive demands placed upon the learner.

Summary

The concept of learning disabilities remains difficult to precisely define, nevertheless, students with LD perform differently from students without LD on a wide variety of performance

measures. Although the category of LD is characterized by problems in the linguistic, achievement, neuropsychological, and social/behavioral domains, no single domain stands out as a primary problem of most individuals with LD. Rather, LD is better conceptualized as a complex and individual-specific mix of all four of these domains. Even within a specific individual, the manifestation of LD may change from task to task and subject to subject because of the interaction of functional overriding and functional undermining of cognitive processes. Clearly, accommodation of students with LD in general education classes is a complicated endeavor. It is unlikely that a blanket approach can meet the needs of all students with LD. Nevertheless, some techniques appear to be strong candidates for supporting students with LD. The likelihood that any technique will work for all students with LD is, however, small. Educators are advised to monitor individual students to ensure that the support they provide yields the outcomes they desire.

Supporting Students with LD in Educational Programs

Mastropieri and Scruggs (1993) identified five areas of functioning that inhibit classroom performance of students with disabilities in classroom learning tasks. These areas are consistent with the domains described by Kavale and Nye (1985-1986) but are more specific to the types of observations that teachers in classrooms are likely to make. The areas are: (a) language and literacy, (b) intellectual and cognitive development, (c) attention and memory, (d) affect and

social behavior, and (e) physical and sensory functioning. The last item, physical and sensory functioning is not a primary characteristic of LD but may exist as a co-occurring condition along with LD. All five of these areas contribute to the general achievement deficits which are noted across students with LD. Some general recommendations can be made for all teachers working with students who have LD, after that, teachers should consider the specific students in relationship to the curriculum that he or she is expected to learn.

General Considerations for Working with Students Who Have LD

The place to start when the goal is supporting students with disabilities is by ensuring that the instruction they receive is excellent and as free from unnecessary obstacles as possible. Most students benefit from higher quality instruction so it makes sense to first examine the teacher and classroom variables. The "hands-on, minds-off" approach to instruction that mentioned earlier is an example of the kind of barrier to achievement that should be examined before the student characteristics.

Mastropieri and Scruggs (1993) provided the following suggestions for working with students who have disabilities, including those with LD. First, remember that each students is an individual and any techniques must be considered in relation to each students and his or her needs.

Second, with appropriate support, most students can succeed in some mainstream settings. The appropriateness of the mainstream setting is based on the goals of the class and the needs of the student, not on the presence or absence of a disability.

Third, working with a competent special education teacher can make things better for both the student and the science teacher. Most special education teachers openly welcome the chance to help other teachers "work with their students."

Fourth, consider the student's IEP objectives. Students in special education are evaluated at the end of the school year on the extent to which they have attained the goals set forth in their Individual Education Plans. Teachers should monitor the extent to which the classes in which students with LD enroll serve the needs identified in the IEP.

Fifth, keep expectations high. Too often, teachers and classmates do tasks for students with disabilities rather than showing them how to do things for themselves. If students with LD are to develop optimally, they must receive the supports to experience legitimate success. Too easy success and false praise actually tend to undermine students' self-efficacy.

Sixth, employ a matter of fact approach to the student's disability. A matter of fact approach downplays the disability and avoids singling the student out more than necessary because of his or her disability.

Seventh, if the student's disability is unfamiliar to his or her classmates, prepare the class for the student with a disability. Special educators and often the parents of the students can be a good resource for disability awareness.

Finally, use effective instruction techniques. In general, these variables appear to improve the achievement of all students. They are crucial for students with disabilities. Mastropieri and Scruggs (1993) provided the following guidelines for effective instruction:

- Use daily and weekly review to be sure that students have retained previously presented information.
- State your objective clearly so that students understand the purpose of the lesson. People learn better when they understand the purpose of the lesson.
- Deliver information clearly and succinctly. Speak with clarity and precision. Avoid unnecessary digressions, and provide clear examples.
- Use the "SCREAM" variables:

  Structure

  Clarity

  Redundancy

  Enthusiasm

  Appropriate rate

  Maintain active participation

- Provide guided practice. Give students a chance to demonstrate their understanding of your lesson with your supervision.
- Provide independent practice. Give students practice at applying the principles of the lesson independently.
- Use formative evaluation. Obtain a measure of their understanding of the lesson material as often as reasonably possible. (p. 5)

Characteristics of Effective Inclusion Programs in Science

Mastropieri et al. (1998) and Scruggs and Mastropieri (1994) identified seven characteristics that were present in successful inclusive science education programs. In sum, successful inclusion programs in science were associated with (a) administrative support, (b) ample support from special education teachers and staff, (c) teachers who maintain a positive and supportive environment where special needs were considered and diversity was valued, (d) activities-oriented science approach, (e) teachers who demonstrated the effective instruction variables, (f) peer assistance for the physical as well as the cognitive demands of the curriculum, (g) teachers who were skilled at disability-specific adaptations. It should be noted, however, that success in these programs was determined by successful participation and completion of the activities. Little data exists to validate the achievement of students of students with LD in inclusive and non-inclusive settings. Mastropieri et al. (1998) reported that students with LD in an inclusive

activities-oriented science program ranked at the median of their class and outperformed many general education students in a textbook-oriented comparison class.

Techniques Related to Students with LD in Science

Reading decoding

Despite the endorsement of activities-based approaches to science education, textbooks remain quite popular. Examinations of science texts suggest that they can often be difficult for students with typical reading. Students with reading disabilities (one of the primary academic features of LD, particularly students identified in the earlier grades) have even more difficulty reading and understanding their textbooks. Reading components of activities-based science programs are also difficult for students with disabilities, but because these programs place less emphasis on reading as the primary means of acquiring information, they are less problematic than textbook approaches.

Tape-recorded textbooks are one obvious source of support for students who have reading decoding disabilities. Students whose reading decoding is so slow and laborious that it undermines their comprehension are most likely to benefit from taped texts. Peer readers can also be used to support students with reading difficulties. Teachers should be aware of the difficulty of the vocabulary and the concepts in the text even when selecting taped texts of readers. Many science books present a great deal of unfamiliar vocabulary, are difficult to understand, and place a considerable "cognitive load" on the reader. Simply providing tapes of

difficult-to-understand material may be an insufficient strategy to support a students with a reading problem in a science class. A number of strategies have been developed to also support comprehension of reading material.

Reading Comprehension

Many students with LD experience comprehension difficulties. Sometimes these are the result of deficits in prior knowledge, failure to link current reading with prior knowledge, lack of comprehension strategies, ineffective use of strategies, or failure to systematically monitor understanding. Often, students with LD present combinations of these problems. No matter what the source of the problem, explicit instruction in comprehension is usually required. Several techniques for comprehension are described below.

Several techniques for activating prior knowledge are already familiar to most teachers. Small group discussions of a topic prior to reading have been effective with many students (Baldwin, Peleg-Bruckner & McClintock, 1985). Some students with LD may need considerations such as "priming the discussion" with pre-teaching of some relevant concepts, or allowing students with recall problems to make contributions early in the discussion before their ideas have been taken by other students.

Another technique which can support students comprehension of reading is semantic feature analysis (Bos & Anders, 1990). A semantic feature analysis (see figure one) takes the form of a matrix with important ideas across the top and related vocabulary along the side. Students then

systematically encode the relationship between the items in each cell using a four items code. A "+" is placed in cells with a positive relationship. A "-" is placed to show a negative relationship. A "0" is used to show no relationship. A "?" is used when students are uncertain about the relationship. The technique can be used along with other comprehension activities such as small group discussion as well as in laboratory activities.

Vocabulary development

For a variety of reasons, students with LD often lack the vocabulary development of their classmates without LD. Clearly, there is more to learning than reciting vocabulary lists. However, if one is going to use language to demonstrate competence in science, it is worth the time to ensure that the students know the necessary language.

Keyword mnemonics are the strongest technique available for teaching vocabulary. In mnemonic instruction, links are explicitly (and pictorially) developed between units of to-be-learned information and information already possessed by the student. Figure two provides an example of a mnemonic illustration linking the metals attracted by a magnet to the word magnet. It uses the acronym "INC" in Magnets, INC to prompt recall of the three metals (iron, nickel, and cobalt). Because cobalt is likely to be unfamiliar to many students, it is represented by the keyword "cobra." At recall, students are instructed to think of the picture of Magnet, INC and think about the things in the picture, one for each letter in the acronym.

Keywords require preparation and devotion of class time to explicit teaching of vocabulary. However, they are probably worth the effort. A substantial body of research exists demonstrating that students can remember keyword-instructed vocabulary for long periods of time and use their vocabulary flexibly and appropriately. Further, work in secondary education suggests that content-specific vocabulary development is the most accurate predictor of grades in core content area classes such as science (Espin & Denos, 1994-1995).

Some science teachers may find it easier to provide such specific vocabulary than others. Additionally, some general education students may already have acquired the necessary vocabulary for instruction and, therefore, find time spent on this technique counterproductive. In such cases, it may be appropriate for special education teachers to "preteach" the necessary vocabulary outside of the given lesson. In some cases, this could be done in a separate area of the classroom or in other cases, this might be better done in a different classroom at a different time. Rather than following the "same place for everything and everyone" ideology, we suggest that teachers and students examine the competing demands of the science classroom and the vocabulary instruction. If a separate environment promotes greater success and less disruption, it is foolish to insist on the same environment. Under certain circumstances, peer-tutoring and computer-based instruction could also be considered to support the acquisition of vocabulary.

Written expression

Many activities-based science classes require students to complete lab notebooks or write descriptions of activities. Writing is probably the most difficult aspect of language and many students with LD have particular difficulty with it. Several excellent programs are available to teach writing skills (e.g., Case, Mamlin, Harris & Graham, 1995; Englert, Raphael, Anderson, Anthony & Stevens, 1991; Harris & Graham, 1992). These programs can be used within science classes, but they are focused on general writing. Science teachers and special education teachers could collaborate to support student writing using these programs if writing is a major focus of the student's IEP and time allows. For other students, supports include alternative forms of expression. Students could dictate their responses to an aide, another student, or to a tape recorder. Speech recognition programs for computers are another option, but these must be "trained" to recognize individual students' voices. Little information is available regarding their effectiveness. For some students, written tasks can be reduced to checklists or multiple choice formats. Teachers should be alert to the extent to which changing the response format changes the learning task. In some cases, the format is easily altered, in others, the response format is important.

<u>Attention</u>

Often students fail to pay attention because they cannot perform the targeted tasks or understand the instruction. Other students are distracted because of personal problems or a history of failure which prevents them from taking instructional risks. Another source of poor

attention is unenthusiastic and dull teacher behavior. Activities-based instruction is one way of reducing attention problems. Most students enjoy working with materials and respond positively. For those who need more help, direct appeals to pay attention, explanations of the relevance of the activities, and reinforcing attention may be helpful. Brigham, Scruggs, and Mastropieri (Brigham, Scruggs & Mastropieri, 1992b) reported that enthusiastic teaching resulted in twice the achievement and only one-third the behavior problems compared to unenthusiastic teaching of the same material to similar students.

Classroom behavior

Classroom behavior is often mediated by the instructional and environmental demands of the classroom. Also, teachers and peers may be inadvertently or intentionally reinforcing misbehavior. Classroom demands and reinforcement patterns are sometimes difficult to identify in one's own class. Asking other science teachers or special education teachers for assistance is one way of identifying classroom aspects which could be easily changed and may modify student behavior. Fuchs and Fuchs (Fuchs, Fernstrom, Scott, Fuchs & Vandermeer, 1994) provided a classroom ecological inventory which can be used by general and special education teachers to examine the "goodness of fit" between a given classroom and student characteristics and needs.

Simple behavior management techniques include direct appeal to the misbehaving student, teacher proximity, reinforcement of appropriate behavior, and group reward systems such as the "Good Behavior Game (e.g., Brigham, Bakken, Scruggs & Mastropieri, 1992a). A number of

more complex techniques are available for classroom use. Because students with disabilities are often participating in structured behavior management programs science teachers should consult with special education teachers or check their students' IEPs. In some cases, misbehavior is involuntary (for example, verbal tics associated with Turret's Syndrome) and should be minimized or overlooked. In other cases, the student's misbehavior is a direct manifestation of a disability and requires more sophisticated intervention. In many cases, however, students with disabilities misbehave for the same reason as students without disabilities. Excusing misbehavior which is not related to a disability probably does more harm than good for students with LD.

Summary

The preceding sections have described a small number of support techniques related to several of the problems that students with LD are likely to display in science classes. In general, supports for students with LD focus on making the tasks clear and within the ability of the students to accomplish by altering the task (e.g., listening instead of reading) or structuring the task to promote better application of student abilities (e.g., systematic comprehending with a semantic-feature analysis. Activities-based approaches tend to minimize attention problems and some forms of behavior problems. Finally, students may need support to demonstrate what they know (e.g., transcriptions and taped responses). When special education teachers and general education teacher work together to provide appropriate support, student achievement is likely to increase substantially. It is important that specific supports be applied appropriately. Misuse of

these supports (e.g., allowing a student who is capable of written response to use taped responses only) can actually be detrimental to students achievement (Mastropieri et al. 1998). Because LD is a complex and variable condition, science teachers should work closely with special education teachers and even the students themselves to tailor supports to promote optimal learning.

The Proper Emphasis for Inclusion in Science Classes for Students with LD

The Dilemma of Inclusion

Given the amount of attention that inclusion has received in recent years, one would suppose that a great deal of empirical support for the construct and its associated techniques has been generated. Unfortunately, inclusion remains as difficult to define as LD and empirical support for full inclusion of all students with disabilities is unavailable (MacMillan, Gresham & Forness, 1996). In fact, for some students, inclusion has been found to be harmful (Brigham & Kauffman, 1998) or associated with unsatisfactory results (Zigmond et al., 1995). Also, the current educational zeitgeist for increasing academic achievement outcomes in the areas of math, science, social studies, and reading and writing skills often works against the goals of socialization in general education settings promoted by advocates of full inclusion (MacMillan et al. 1996).

Application of Science Best Practices

Activity-based science practices have been shown to be beneficial for including students with mild learning disabilities. The learning cycle model of instruction should be adaptable for

most students in this category, if modifications are considered. For example, the exploration stage of the learning cycle should be structured so that LD students can determine what aspects of the activity to focus upon. The BSCS model of the learning cycle, with the addition of an engagement stage prior to exploration, provides additional support for LD students. The engagement stage can involve discussion and introduction of important vocabulary, and can introduce important questions for students to think about during the exploration of the phenomenon or concept. When using the engagement stage as an additional part of the learning cycle, it is important for teachers to avoid a much-used and abused traditional approach - that of assigning a list of vocabulary words for students to look up in a dictionary and define. This approach emphasizes the reading and writing weaknesses in LD learners, and establishes little in the way of concept development. Direct instruction can be beneficial to LD students if delivered with consideration of the reading and writing deficits of these students and if the relevance of the instruction is established by appropriate engagement and exploration activities.

Learning disabled students need some structure in instruction; but they benefit from freedom to explore physical phenomena. They can become frustrated and display disruptive and counter-productive behaviors if the instruction is too open-ended. Therefore, science teachers must carefully apply the more open-ended interpretations of inquiry-based instruction. Whether a teacher calls the instruction constructivist, Socratic method, or open-ended laboratory

exploration, the teacher must provide some level of guidance in order for learning disabled students to gain from the instruction.

Though structure is comforting to learning disabled students, there is a possibility of too much structure in science lessons that are based upon reading and writing tasks. Traditional approaches such as copying notes, completing worksheets, and answering questions after reading sections of text can be as frustrating and counter-productive as approaches that are too open-ended. The problem with LD students and science instruction can be characterized by the dilemma faced by Goldilocks with the temperatures of the porridge. Teachers must ask themselves if the instruction is too open-ended, too structured, or just right.

Summary

We have not yet discovered the one model of science instruction that works for all students, and such a perfect approach may not exist. Of the existing models and the best practices that are coupled with those models, no approach can meet the needs of all learning disabled students. Science educators must work with special education specialists to determine the best practices for particular students. There is no magic model. While we are able to support the goals of greater inclusion of individuals into society and educational systems, the evidence regarding elimination of separate programs for all students with disabilities suggests that such a step is at least premature if not unjustifiable. Inclusion of students with disabilities in general education settings should not be viewed as an either-or proposition. To be against full inclusion does not

mean that one is for exclusion (Lieberman, 1992). Supporting students with disabilities in general education creates another highly desirable option for education of students with disabilities and is, therefore, an appropriate area of endeavor with the potential to improve the education of many but not all students with disabilities. It is only through a thoughtful and empirically based analysis of particular situations that science educators and special education specialists can move our learning disabled students toward the understandings they need for science literacy.

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